Structure and Properties of Atoms

PS-2 The student will demonstrate an understanding of the structure and properties of atoms.

PS-2.6 Compare fission and fusion (including the basic processes and the fact that both fission and fusion convert a fraction of the mass of interacting particles into energy and release a great amount of energy).
Taxonomy Level: 2.6-B Understand Conceptual Knowledge

Key Concepts:
Nuclear fission: chain reaction, critical mass
Nuclear fusion

Previous/Future knowledge: Students have not been introduced to fission and fusion prior to Physical Science. Students were introduced to nuclear decay in indicator PS-2.2. Fission and fusion are two very different nuclear reactions. Students often confuse chemical reactions with nuclear reactions. It is therefore essential that students understand the processes of nuclear reactions to the extent that they can differentiate them from chemical reactions, and also to understand the roles that nuclear processes have in global affairs (PS-2.7).

It is essential for students to
- Understand that nuclear reactions involve the particles in the nucleus of the atom (as opposed to chemical reactions, which involve the electrons in an atom and where the nucleus remains intact).
- Understand that there is a great deal more energy change involved in nuclear reactions than in chemical reactions.

Nuclear fission
- Understand the processes of *nuclear fission*
  - *Nuclear fission* occurs when a heavy nucleus, such as the U-235 nucleus, splits into two or more parts, a large amount of energy is released.
    - The absorption of a neutron by a large nucleus (such as U-235) is one way to initiate a fission reaction.
    - When an atom with a large nucleus undergoes fission, atoms that have smaller nuclei result. In the process smaller particles, such as neutrons, may be ejected from the splitting nucleus.
    - If one or more ejected neutrons strike another U-235 nucleus, another fission reaction may occur. The continuation of this process is called a *chain reaction*. There must be a certain minimum amount of mass, called a *critical mass,* of fissionable material in close proximity for a chain reaction to occur.
  - Understand that fission is the type of nuclear reaction that occurs in nuclear power plants and other nuclear applications (atomic bombs, nuclear-powered submarines and satellites).
  - Understand that the mass of the products of a fission reaction is less than the mass of the reactants.
    - This lost mass (m) is converted into energy (E). The equation $E = mc^2$ shows the relationship of this "lost mass" to the energy released. (It is **not** essential for students to use this equation.)
    - The conversion of mass to energy during a nuclear reaction involves far more energy than the amount of energy involved in a chemical reaction.

Structure and Properties of Atoms

PS-2 The student will demonstrate an understanding of the structure and properties of atoms.

Nuclear fusion

- Understand the processes of *nuclear fusion*
  - *Nuclear fusion* occurs when light nuclei (such as hydrogen) fuse, or combine, to form a larger single nucleus (such as helium).
  - As in fission reactions, in fusion reactions the mass of the products is less than the mass of the reactants and the "lost mass" is converted to energy.
  - Fusion is the type of nuclear reaction that occurs on the sun (and other stars).
  - Forcing small nuclei to fuse requires huge amounts of energy; however, when fusion reactions occur on the sun, more energy is released than the amount of energy required to produce the reaction.
  - Using fusion for nuclear power plants is still in the developmental stage.
  - A hydrogen bomb, also called a thermonuclear bomb, utilizes nuclear fusion.

It is not essential for students to

- Understand nuclear binding energy, or the dual nature of matter and energy;
- Use the equation $E = mc^2$ or explain the equation in any depth; (Students are generally familiar with the equation so mentioning it brings relevance to the concept.)
- Write or balance nuclear equations for fission or fusion nuclear reactions.

Assessment Guidelines:

The objective of this indicator is to *compare* fission and fusion, therefore, the major focus of the assessment should be to identify the similarities and differences in fission and fusion, the consequences, and the applications of the two processes.

In addition to *compare*, assessments may require students to

- *Exemplify* relevant uses of each process;
- *Classify* a process as either fission or fusion;
- *Summarize* major points about the steps in each process;
- *Illustrate* the process in a diagram format;
- *Recognize* each process from an illustration.